EYE GAZE TRACKING UTILIZING SURFACE NORMAL IDENTIFICATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. application Ser. No. 14/282,437, filed May 20, 2014 and titled "Gaze Tracking for a Vehicle Operator," the entire disclosure of which is expressly incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure generally relates to a system and a method for tracking the gaze of a vehicle operator.

BACKGROUND

[0003] Vehicle operators (e.g., drivers) regularly make visual scans of their environment (both external and internal to the vehicle). These visual scans frequently occur with regard to objects on or near a road (e.g., to view road signs, pedestrians near the road, etc.) and with regard to objects in the cabin of the vehicle (e.g., to view console readings such as speed, to operate a radio or other in-dash devices, or to view/operate personal mobile devices). Failure to properly scan one's environment can result in a driver failing to observe obstacles or people near the vehicle. Poor scanning behavior not only increases a driver's risk of causing an accident, but decreases his or her odds of successfully taking evasive action in response to unsafe behavior of others. In some instances, a driver may not even realize he or she exhibits unsafe scanning behavior. For example, safer and more experienced drivers generally have a relatively long gaze and good peripheral awareness. In other words, such drivers typically scan a large percentage of important areas, enabling the drivers to react to potential risks far ahead of the vehicle as well as those near the vehicle. By contrast, inexperienced drivers often have short-distance focus that is centrally located. Such scanning behavior puts the driver at risk of failing to observe peripherally located risks, as well as those located at a distance in front of the vehicle.

SUMMARY

[0004] Features and advantages described in this summary and the following detailed description are not all-inclusive. Many additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims of this patent. Additionally, other implementations may omit one or more (or all) of the features and advantages described in this summary.

[0005] A gaze tracking system may include an image sensor device positioned within a vehicle to capture images of a vehicle operator's head. The gaze tracking system may also include a gaze analysis system to analyze the captured images, detect facial features, and determine gaze direction. The gaze tracking system may track the position of facial features over time. Example facial features that may be detected and tracked include an eye, an eye pupil, an eye iris, a nose, a mouth, or some combination thereof. The gaze tracking system may determine the vehicle operator's head pose and/or gaze direction based on the positions of the detected facial features. The images may be captured and analyzed in near-real time. By tracking movement of the driver's head and/or facial features over time, the gaze analysis system may predict or estimate head position and/or gaze direction when one or more facial features are not detected. The gaze tracking system may generate a report regarding the vehicle operator's gaze distribution. The report may be saved to memory and may be graphically displayed at a screen. For example, a heat map may be displayed to show how much the operator gazes in the direction of particular areas.

[0006] In an embodiment, a gaze tracking system includes an image sensor device positioned on or within a vehicle such that the image sensor device may capture an image of an operator interface area in the vehicle. A gaze tracking system may further include one or more processors communicatively coupled to the image sensor device and one or more memory devices communicatively coupled to the one or more processors. The one or more memory devices may comprise instructions that when executed cause the one or more processors to track an eye gaze direction. For example, the one or more processors may: (i) detect a plurality of triangles in a sequence of images captured by the image sensor device, each triangle in the plurality of triangles having vertices corresponding to three facial features of the driver of the vehicle; (ii) analyze the detected plurality of triangles in the sequence of images to identify a plurality of surface normals for the detected plurality of triangles; and/or (iii) track an eye gaze direction of the driver over the time period by tracking the identified plurality of surface normals for the detected plurality of triangles. The three facial features may include: a first pupil, a second pupil, and a third feature selected from a group consisting of a nose, a mouth, and a chin.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** illustrates a block diagram of an exemplary gaze tracking system according to an embodiment.

[0008] FIG. **2**A-**2**D illustrate example gaze tracking systems according to the described embodiments.

[0009] FIG. **3** illustrates an example method for gaze tracking in accordance with the described embodiments.

[0010] FIG. **4**A-**4**C illustrate example images of a face of an operator that may be analyzed by the gaze analysis system according to an embodiment.

[0011] FIG. **5** illustrates example images of eyes that may be analyzed by the gaze analysis system according to an embodiment.

[0012] FIG. **6** illustrates example images of a face of an operator that may be analyzed by the gaze analysis system according to an embodiment.

[0013] FIG. **7**A-**7**C illustrates example images and reference patterns that may be utilized to detect facial features in accordance with the described embodiments.

[0014] FIG. **8** illustrates an example method for facial feature detection in accordance with the described embodiments.

[0015] FIG. **9** illustrates an example display displaying a report in accordance with the described embodiments.

DETAILED DESCRIPTION

[0016] The figures described below depict various aspects of the system and methods disclosed herein. It should be understood that each figure depicts an embodiment of a particular aspect of the disclosed system and methods, and that each of the figures is intended to accord with a possible